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THE EFFECT OF ALKALI TREATMENT ON THE MECHANICAL PROPERTIES OF SISAL FIBER REINFORCED EPOXY COMPOSITES

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ABSTRACT

This present work has investigated the effect of alkali treatment (concentration of 0%, 3%, 6% and 9% NaOH solution) on the mechanical properties of sisal fiber reinforced epoxy composites. This composite is prepared by using compression molding technique with 20wt% of sisal fibers. Sisal fiber is used as reinforced and epoxy as matrix in this composite. All test specimens were prepared as per ASTM standard. The mechanical properties such as tensile strength, flexural strength and impact strength of composites were studied and compared. The tensile strength and flexural strength of alkali treated fiber composites are improved compared to the untreated fiber composites. But, the impact strength of alkali treated fiber composites were decreased compared with the untreated fiber composites.

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INTRODUCTION

Composites are a combination of two materials in which one of the material is called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other material called the matrix (James Holbery *et al.,* 2006). Matrix surrounds the fibers, acting as load transferring medium and thus protecting those fibers against chemical and environmental attack.

Natural fibers are an attractive research area because they are eco-friendly, renewable, abundant, flexibility in usage, non-toxicity, light weight, low cost and bio degradability (Araújo, *et al.,* 2008; van Voorn, *et al.,* 2001; Mohanty, *et al.,* 2003). Sisal, jute, coir, banana etc., are good example of natural fibers (Idicula, *et al.,* 2005; Jacob, *et al.,* 2004; Brahmakumar, *et al.,* 2005). The main drawback of natural fibers are their high level of moisture absorption and weak adhesion to matrix (Mohanty, *et al.,* 2003; Venkateshwaran,

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et al., 2011; Joseph, *et al.,* 2002). The natural fibers are consisting of cellulose, hemi-cellulose, lignin, pectin, waxes etc., (Avinash, *et al.,* 2015; Naveen, *et al.,* 2015). The surface of natural fiber is usually not suitable for creating a strong bond with a polymeric matrix. The natural fibers can be treated to improve the adhesion to matrix materials and to stop the moisture absorption process (Romao, 2003). Different types of chemical treatment such as alkali(mercerization), silane, benzoylation, peroxide etc. are used to treat the natural fibers (Wang, *et al.,* 2007; Avinash, *et al.,* 2015). The alkali (NaOH) treatment is the most common method that has been used for the treatment of natural fiber (sisal, jute, coir etc.) because this method is simple and inexpensive (Naveen, *et al.,* 2015; Aziz, *et al.,* 2004). The concentration of alkali solution used to treat the fibers is in the range of 0.5% up to 28%, but most of the researchers use below 10% alkali solution. The temperature and soaking time to treat the natural fiber in the solution are in the range of 20-180°C and 15minutes to 48 hrs., period of time respectively (Naveen, *et al.,* 2015).

Depending on the type of matrix materials used composite materials can be classified into three categories such as metal matrix composites, ceramic matrix composites and polymer matrix composites. Most commonly used matrix material in composite materials is polymer. Because, the processing of polymer matrix composite does not require high pressure and temperature. There are two major classes of polymers used as matrix materials such as thermoplastics and thermosets. Thermoplastics (polypropylene, nylons, acrylics etc.), can be repeatedly softened and re-formed by application of heat. However, thermosets (epoxy, polyester, polyurethane etc.) on the other hand, the materials that undergo a curing process during part fabrication, after which they are rigid and cannot be re-formed. Epoxy resin is the most widely used matrix due to its advantages like good adhesion to other materials, high strength, low volatility during cure, low shrink rate, low viscosity etc., (Naveen, *et al.,* 2015; Chenhui Zhao, *et al.,* 2012). The mechanical properties of natural fiber reinforced composite depends on many parameters, such as fiber strength, volume fraction of the fibers, fiber length, fiber-matrix adhesion etc., (Srinivasa, *et al.,* 2011).

In this study, sisal fiber was selected and treated with help of different concentration of NaOH solutions. In this work a polymer matrix composite was prepared using untreated and treated sisal fiber as a reinforcement and epoxy as matrix material. The effect of alkali (0%, 3%,6% & 9%NaOH solution) treatment on the mechanical properties (tensile strength, flexural strength and impact strength) of sisal fiber reinforced epoxy composites are discussed.

1.1 Objectives

The objectives of the project are outlined below.

- To extract the sisal fiber from the leaves of sisal plant.
- To treat the raw sisal fiber by using NaOH solutions.
- To select the appropriate untreated and treated sisal fibers used as reinforcement for epoxy composites and to prepare the sisal fiber reinforced epoxy composites.
- To prepare test specimen according to the ASTM standards.
- To investigate the tensile, flexural and impact strength of composites.

MATERIALS AND METHODS

2.1 Matrix and Hardener

The epoxy resin is selected as the matrix. Epoxy resin (LY556) is a thermosetting polymer that cures when mixed with a hardener (HY951). The Epoxy resin and the hardener were mixed in ratio of 10:1 by weight. The epoxy resin and hardener were purchased from Covai Seenu & Co, Coimbatore, Tamil Nadu, India.

2.2 Extraction of Sisal Fiber

Sisal fibers are extracted by the following methods.

(1) Mechanical extraction.
(2) Chemical extraction.
(3) Retting process:

2.2.1 Retting Process:

The sisal leafs are cut from sisal plant and it was immersed in water (river, pond or tank) for 15 days until it becomes decay. The retted leafs were washed in running water and then sisal fiber was cleaned. The obtained fiber was dried under sunlight for 2 days. This process takes more time but it is economical.

2.3 Alkali Treatment of Sisal Fiber

The dry sisal fibers were soaked in different concentrations (0%, 3%, 6% & 9%) of NaOH solution for 75 minutes at room temperature. The fiber to solution weight ratio was maintained at 1:20. After complete alkali treatment, the sisal fibers were washed with distilled water to remove the excess of NaOH sticking on the fibers. The washed fibers were dried in sunlight to remove the moisture. The dried alkali treated fiber were chopped in to 150 mm and stored in a seated plastic bag.

2.4 Fabrication of Composites

A steel mold is used for preparing the test specimen and having dimension of 300mm x 300mm x 3mm. The mold was coated with mould releasing agent enabling easy removal of the composite from the mold. The matrix was prepared by mixing the hardener to epoxy resin. The epoxy resin and hardener were mixed in ratio of 10:1 by weight. The epoxy resin and hardener is mixed smoothly and slowly for approximately 10 minutes. The composite specimens for both untreated and treated fibers were made by compression molding technique using 20wt% of sisal fibers. Initial layer of the mould was filled with epoxy resin mixture and then fibers was spread over the resin mixture. Again, epoxy mixture is poured on the sisal fibers. The composite specimen consists total of three layers in which sisal fiber layers are in the middle of the specimen. The specimens were allowed to uniformly cure for 45minutes at 85^0C temperature. After completing curing process composites were cut as per ASTM standard.

MECHANICAL TESTING

The main objective is to determine three important mechanical properties of composite by conducting the following test.

3.1 Tensile Test

The tensile test specimens were prepared according to ASTM D3039; the most common specimen for ASTM D3039 has a constant rectangular cross section. The specimen size is 250mm x 25mm x 3mm. Tensile tests were conducted using computerized universal testing machine with a cross head speed of 2mm/min. Tests were carried out at room temperature and each test was performed until tensile failure occurred. In each case, three samples were tested. The tensile strength was reported in MPa.

3.2 Flexural Test

The flexural test measures the force required to bend a beam under three-point loading conditions. Flexural test is also known as bending test and applying a concentrated load (point load) at the center of the specimen until it fracture and breaks. The testing was done as per ASTM D790 with the help of computerized UTM at cross head speed of 2mm/min and at room temperature. The standard specimen size for ASTM D790 is 127mm x 13mm x 3mm. Three composite samples were tested for each case and flexural strength was reported in MPa.

3.3 Impact Test

Impact strength is the ability of a material to absorb energy under a shock load. Impact test unnotched specimens are prepared and the dimensions are (66mm x 13mm x 3mm) based on the ASTM D256 standards. The impact test was carried out using impact test machine at room temperature and impact strength was reported in J/m. In each case, three samples were tested.

RESULTS AND DISCUSSION

4.1 Mechanical Testing

After fabrication the test specimens were subjected to three important mechanical tests as per ASTM standards. All tests were performed at room temperature.

Figure – 1: *Tensile Test Specimens*

Figure – 2: *Flexural Test Specimens*

Figure – 3: *Impact Test Specimens*

4.2 Tensile Test

The tensile strength is defined as the maximum tensile load that a body can withstand before failure, divided by its cross sectional area. This property is also sometime referred to ultimate tensile stress. The four different composite specimens are tested in the computerized universal testing machine to find the tensile strength. Tensile test specimens are shown in figure-1. Three samples were tested for each composition of the composites and each test was performed until failure occurred. From table-1 and figure-4, the results indicate that the tensile strength of the 3% NaOH treated fiber composite is high (55.02MPa). It is found that tensile strength of 3% NaOH treated fiber composite is 1.12 times higher than untreated fiber composite. This enhancement is due to the removal of the hemi cellulose, waxes, lignin and other impurities creating a rough surface topography on the sisal fiber and offering a better fiber-matrix interfacial adhesion. From the results of the tensile test, it can be concluded that the 3%NaOH treated fiber composite is well performing compared with other types of composites. Mardiyati, *et al*., (2016) whose work was on Effects of alkali treatment on the mechanical and thermal properties of Sansevieria trifasciata fiber reported similar behaviour. The fibers were treated with different concentrations of NaOH (0%, 1%, 3% and 5%). It was found that the maximum tensile strength was obtained for the fibers that have been treated with 3% NaOH.

4.2.1 Formula

Tensile Strength = P/A

Where

P = Ultimate (Peak) load (N)

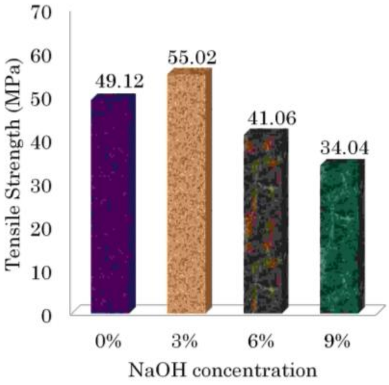
A = Area of the specimen. (mm^2)

A = 25mm x 3mm = $75mm^2$

Table – 1: *Tensile Test Result*

Sl. No.	NaOH treatment	Ultimate (peak) Load (N)			Avg. Peak Load (N)	Tensile strength (MPa)
		Sample 1	Sample 2	Sample 3		
1	0%	4129.902	3081.566	3841.331	3684.266	49.12
2	3%	4583.889	4475.734	3320.911	4126.844	55.02
3	6%	3348.045	3397.075	2493.398	3079.506	41.06
4	9%	2819.767	2224.663	2616.160	2553.530	34.04

Figure – 4: *Tensile Strength of Composites*



4.3 Flexural Test

Flexural Strength is defined as the materials ability to resist deformation under load. Flexural test specimens are shown in figure-2. From table-2 and figure-5, it is clearly evident that the flexural strength of the 6% NaOH treated fiber composite is higher (122.27MPa) than other three types of composites. The increase of NaOH concentration from 0%to 6% increase the flexural strength of composites. The flexural strength of 6% NaOH treated sisal fiber composite is 47.77% higher than untreated sisal fiber composite. Thus, it can be concluded that the flexural strength of the sisal composites may decrease after certain optimum NaOH concentration, which in this study was found at 6%NaOH. This concentration is just enough to remove the waxy material from the surface of the sisal fiber resulting in an increased fiber-matrix interfacial strength and better properties of composites. Similar results were found by Allan C. Manalo *et al.,* whose work was on Effects of alkali treatment and elevated temperature on the mechanical properties of bamboo fiber polyester composites reported similar behaviour. The fibers were treated with different concentrations of NaOH (0%, 4%, 6% and 8%). Maximum flexural strength was obtained from 6%NaOH treated fiber composite compared to other three types of fiber composites.

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4.3.1 Formula

Flexural Strength = $(3PL)/(2bt^2)$

Where

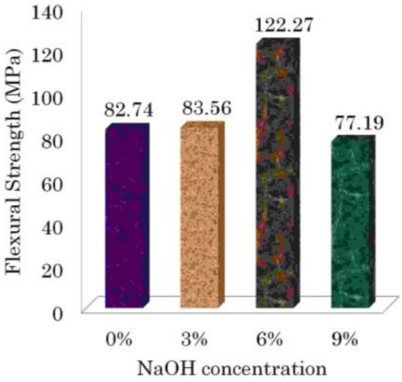
P = Maximum(Peak) load (N)
L = Length of the Support Span (mm) = 63mm.
b = Width of the specimen (mm) = 13mm.
t = Thickness of specimen (mm) = 3mm.

Table – 2: *Flexural Test Result*

Sl. No.	NaOH treatment	Ultimate(peak) Load (N)			Avg. Peak Load (N)	Flexural strength (MPa)
		Sample 1	Sample 2	Sample 3		
1	0%	104.172	101.121	102.063	102.452	82.74
2	3%	117.180	090.909	102.289	103.459	83.56

3	6%	158.137	110.255	185.772	151.388	122.27
4	9%	090.654	076.234	119.829	95.572	77.19

Figure – 5: *Flexural Strength of Composites*



4.4 Impact Test

Impact strength is the ability of a material to absorb energy under a shock load or the ability to resist the fracture under load applied at high speed. The izod impact testing machine has been used for measuring impact strength. Impact test specimens are shown in figure-3. The impact strength of composites is presented in table-3 and figure-6. It is observed that untreated fiber composite has a higher impact strength value of 490 J/m compared to 3%, 6%, and 9% NaOH treated samples with values of 276.67 J/m, 183.33 J/m and 183.33 J/m respectively. This could be mainly due to the reason that during the impact considerable part of energy absorption takes place through the fiber pull-out process, but after alkali treatment, due to the removal of soluble greasy contents from the fiber, strong mechanical interlocking develops between fiber and matrix, and fiber pull-out is minimized. This, in turn, will decrease the impact strength. X. Y. Liu, *et al.*, (2007) whose work was on Surface modification and micromechanical properties of jute fiber mat reinforced polypropylene composites reported similar behaviour. The fibers were treated with different concentrations of NaOH (0%, 2% and 5%). The untreated fiber composite has a higher impact strength compared to alkali treated fiber composites.

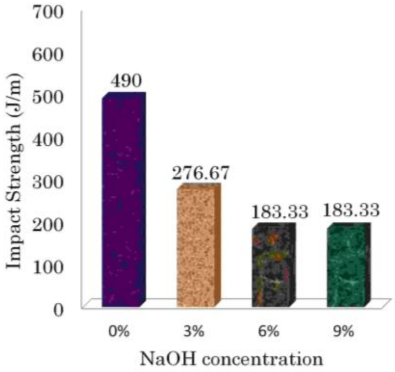
4.4.1 Formula

Impact strength = (Energy absorbed) / (Specimen thickness)
Specimen thickness = 3mm= 0.003m

Table – 3: *Impact Test Result*

Sl. No.	**NaOH treatment**	**Energy absorbed by the specimen (J)**			**Avg. impact energy(J)**	**Impact strength (J/m)**
		Sample 1	**Sample 2**	**Sample 3**		
1	0%	1.10	1.10	2.20	1.47	490.00
2	3%	0.90	0.95	0.65	0.83	276.67
3	6%	0.50	0.65	0.50	0.55	183.33
4	9%	0.65	0.65	0.35	0.55	183.33

Figure – 6: *Impact Strength of Composites*



CONCLUSIONS

The effect of alkali treatment on the mechanical properties of sisal fiber reinforced epoxy composites was studied. The following conclusions are made from the results and discussions.

- The 3% NaOH treated fiber composite has maximum tensile strength of 55.02 MPa.
- The 6% NaOH treated fiber possess good flexural strength up to 122.27 MPa compared to other composites.
- The maximum impact strength is obtained for the untreated fiber composite and has the value of 490J/m.

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